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Field Experiments on Survival Rates of Caged and Released Red Snapper

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Abstract.—Survival of red snapper *Lutjanus campechanus* captured by hook and line and then released was evaluated by two methodologies: release into cages and surface release. Fish captured at a depth of 50 m off the northeastern Texas coast were placed in cages, lowered to a depth of 35 m, and monitored at irregular intervals by scuba divers for 10–15 d. Sixty-four percent of caged red snapper survived. There was no significant difference in survival due to size (<30 cm versus ≥30 cm fork length; $P = 0.59$, $N = 55$) or to gas bladder eversion from the oral cavity ($P = 0.13$, $N = 45$). No predation on red snapper released at the surface was observed. Survival rates were 99%, 90%, and 56% for fish captured at depths of 21–24 m, 27–30 m, and 37–40 m, respectively. Survival rates varied significantly with depth ($P = 0.00$, $N = 232$), suggesting an inverse relationship between survival and capture depth.

The red snapper *Lutjanus campechanus* is found throughout the Gulf of Mexico and along the east coast of the United States. It has been an important commercial species since the late 1800s (Bradley and Bryan 1974), and it is considered a premium target for sport and commercial fishers. Studies of population dynamics during the 1980s indicated declining red snapper stocks (Parrack and McClellan 1986;[1] Gutherz and Pellegrin 1988). More recently, increased commercial and recreational fishing pressure, together with mortality of red snapper taken as bycatch in shrimp trawls, resulted in severe overfishing (Goodyear 1988, 1991; Goodyear and Phares 1990; Muller 1990). In an attempt to increase stocks, federal regulations established size and catch limits for red snapper taken in the Federal Conservation Zone (FCZ) of the Gulf of Mexico and Atlantic Ocean. Fishers have a bag limit of seven fish and are required to release snapper measuring less than 30 cm fork length (FL). The success of this management strategy depends on the survival of released fish.

Critics of regulations requiring the release of red snapper predict high mortality after release and claim that size limits may not be an effective management tool for the fishery. Although few researchers have described direct observations of survival of red snapper and other reef fish (Parker 1985, 1991; Fable 1993; Collins, in press; Render and Wilson, in press), several other investigators have addressed survival and related topics (Gotshall 1964; Tong 1978; Fable 1980; Harper et al., in press). It is widely known that capture depth plays a critical role in survival of released fish (Gotshall 1964; Fable 1980), especially for physoclistic species.

The primary objective of our experiments was to determine the survival rates of undersize and legal size red snapper captured with hook and line at 20–50-m water depths. A secondary objective was to investigate the effect on survival of manually venting gas bladders everted from the oral cavity.

Methods

During the fall of 1985, survival rates of red snapper captured at several water depths off the northeastern Texas coast were estimated with two types of experiments: a study of captured fish placed in cages and a surface release study. Because distension of the gas bladder can prevent submergence of released fish and cause mortality, survival of fish with and without vented gas bladders was compared. The venting procedure is described in the next section.

Survival in cages.—The cage study was conducted at an offshore gas production platform (Tenneco HIA 270B) approximately 140 km southeast of Galveston, Texas. Fish were captured on the sea bottom with rods and sportfishing reels powered by 12-V batteries. Each fish was brought to the surface, dehooked, measured, and observed for signs of stress including fish hook ingestion, bleeding, gas escapement beneath scales, intestinal

[1] This and other unpublished reports are listed separately in the appendix.

TABLE 1.—Numbers of red snapper given various gas bladder treatments in relation to depth of capture and size-class.

Capture depth and fish size (fork length)	Gas bladder condition			Total
	Uneverted	Everted, vented	Everted, unvented	
Cage study				
50 m				
<30 cm	14	5[a]	0	19
≥30 cm	23	5[a]	8	36
Surface release study				
21–24 m				
<30 cm	136	0	2	138
≥30 cm	2	0	0	2
27–30 m				
<30 cm	14	3[b]	10	27
≥30 cm	0	0	4	4
37–40 m				
<30 cm	22	0	25	47
≥30 cm	3	0	11	14

[a] Three of five survived.
[b] Two of three swam down.

protrusion from the anus, and distension of the gas bladder (which can cause the stomach to evert through the oral cavity). Except on a few occasions when several fish were captured simultaneously, fish were individually placed in numbered chicken-wire cages (0.6 m × 0.6 m × 0.6 m) and deployed over the side of a platform. Cages remained at 35 m for the duration of the experiment except when one descent line parted and sent 12 live, caged fish to 46 m. Survival of caged fish was monitored by scuba divers at irregular intervals over a 10–15-d period. Gas bladders of five fish measuring less than 30 cm FL and five measuring 30 cm FL or more were vented with a syringe needle or fish hook before the fish were placed in the cages (Table 1).

Surface release study.—Red snapper captured at 21–40-m depths on rods and manually operated reels during three, 1-d headboat trips were measured, observed for gas bladder eversion from the oral cavity, and released at the surface. Additional red snapper captured by patrons aboard the headboat were observed for bladder eversion, although these fish were not available for release. Two-man scuba teams monitored fish behavior during descent and watched for predators and predation. Nine dives totalling 160 min were made to observe red snapper and other species released on the surface. To conserve underwater time, divers did not descend below 24 m. Shipboard observers noted the number of red snapper floating at the surface that were unable to return to depth. Chi-square and Fisher's exact tests were used to analyze test variables for cage and surface release studies.

Results

Survival in Cages

Caged fish ranged from 25 to 43 cm FL. Trauma related to capture was common. Fifty-one percent (28 of 55) of red snapper displayed signs of capture-related stress due either to partially ingested hooks or to hyperbaric trauma, which included distension of the gas bladder with resulting stomach eversion from the oral cavity, intestinal protrusion from the anus, bleeding, or gas escapement from beneath scales. Survival of fish with external stress symptoms was not significantly different from survival of fish without symptoms (Table 2). The occurrence of stress symptoms and the survival of stressed fish were statistically unrelated to size (legal versus undersize; Table 2). Overexpansion of gas bladders caused stomachs to evert from the oral cavities of 33% (18 of 55) of fish (Table 1). Because no significant differences in survival could

TABLE 2.—Summary of chi-square and Fisher's exact test (FET) results for red snapper survival. Asterisk denotes significance at $P \leq 0.05$*.

Test comparison or variable	Test used		N	P
	Chi-square	FET		
Cage study				
Unvented everted bladder versus vented everted bladder		×	18	0.23
Unvented everted bladder versus uneverted bladder	×		45	0.13
Stressed[a] versus unstressed	×		55	0.65
Undersize versus legal size	×		55	0.59
Fish with stress symptoms:[a] undersize versus legal size		×	28	0.38
Surface release study				
Capture depth	×		232	0.00*

[a] Stress symptoms include fish hook ingestion, bleeding, gas escaping from beneath scales, intestinal protrusion from anus, and eversion of gas bladder from oral cavity.

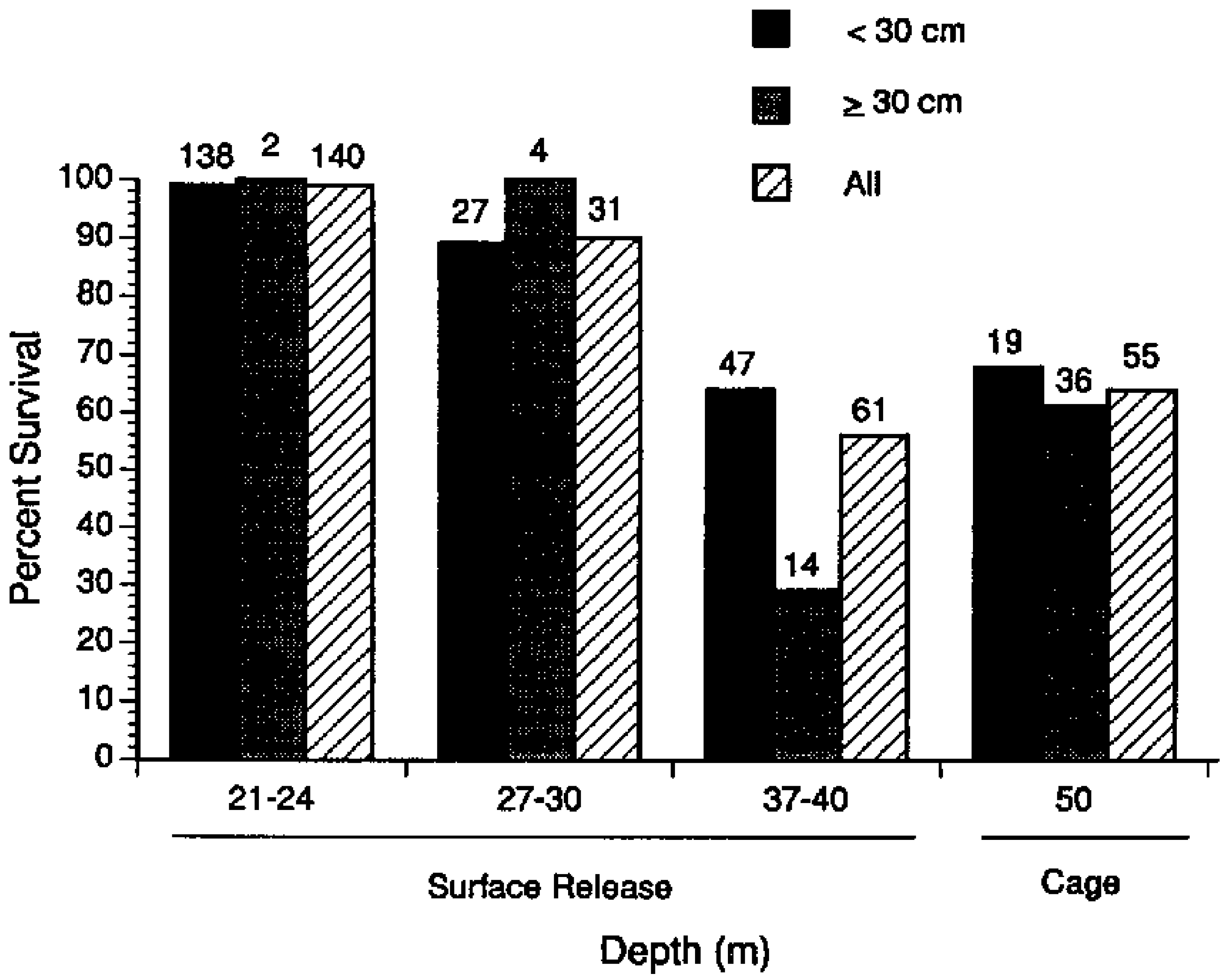

FIGURE 1.—Survival of caged and surface-released red snapper by size (fork length) and capture depth. Sample size is shown at the top of each histogram.

be attributed either to bladder eversion or to venting of everted bladders (Table 2), gas bladder condition was ignored in further analyses.

Survival of all caged red snapper was 64% (Figure 1). Frequency of survival by size is shown in Figure 2. Survival of legal and undersize fish was not significantly different (Table 2). Ninety percent of all deaths occurred during the first day of the experiments and 95% occurred by the end of the second day (Figure 3).

Surface Release Study

Results of surface release studies pertain primarily to undersize red snapper, because 212 of 232 fish in the experiments were less than 30 cm FL. All fish observed actively swimming down from the surface were recorded as survivors. Subsequent mortality could not be measured, so these survival data represent maximum values. Maximum survival rates for red snapper captured at depths of 21–24 m, 27–30 m, and 37–40 m were 99%, 90%, and 56%, respectively (Figure 1). Depth-related differences in survival were highly significant (Table 2), suggesting an inverse relationship between survival and capture depth.

The occurrence of everted gas bladders was significantly lower at the shallowest capture depth (P = 0.00 for all three depths; P = 0.98 for the two deepest depths). Everted gas bladders occurred in

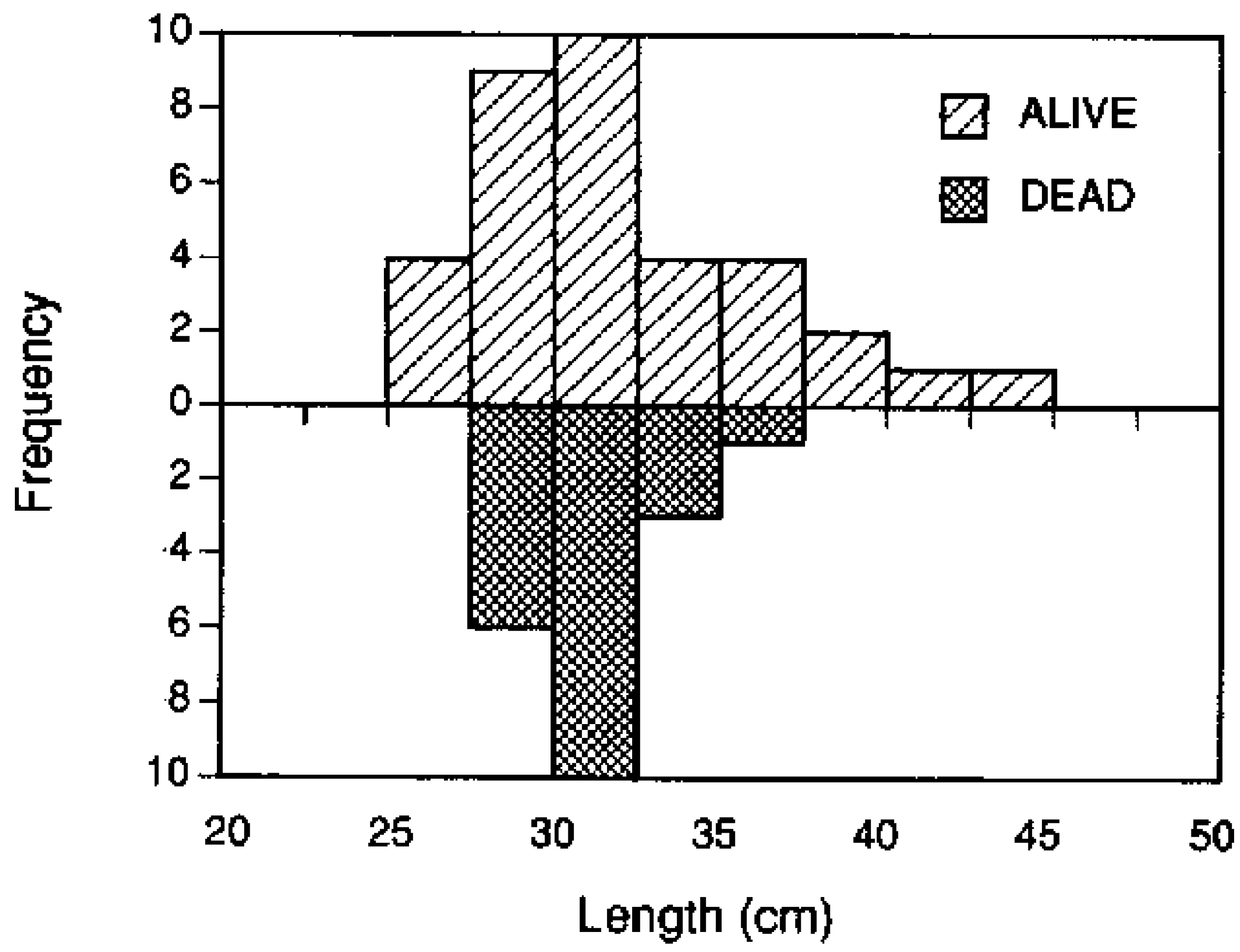

FIGURE 2.—Length-frequency histogram of survival and mortality for caged red snapper captured at 50-m depths. Length is fork length.

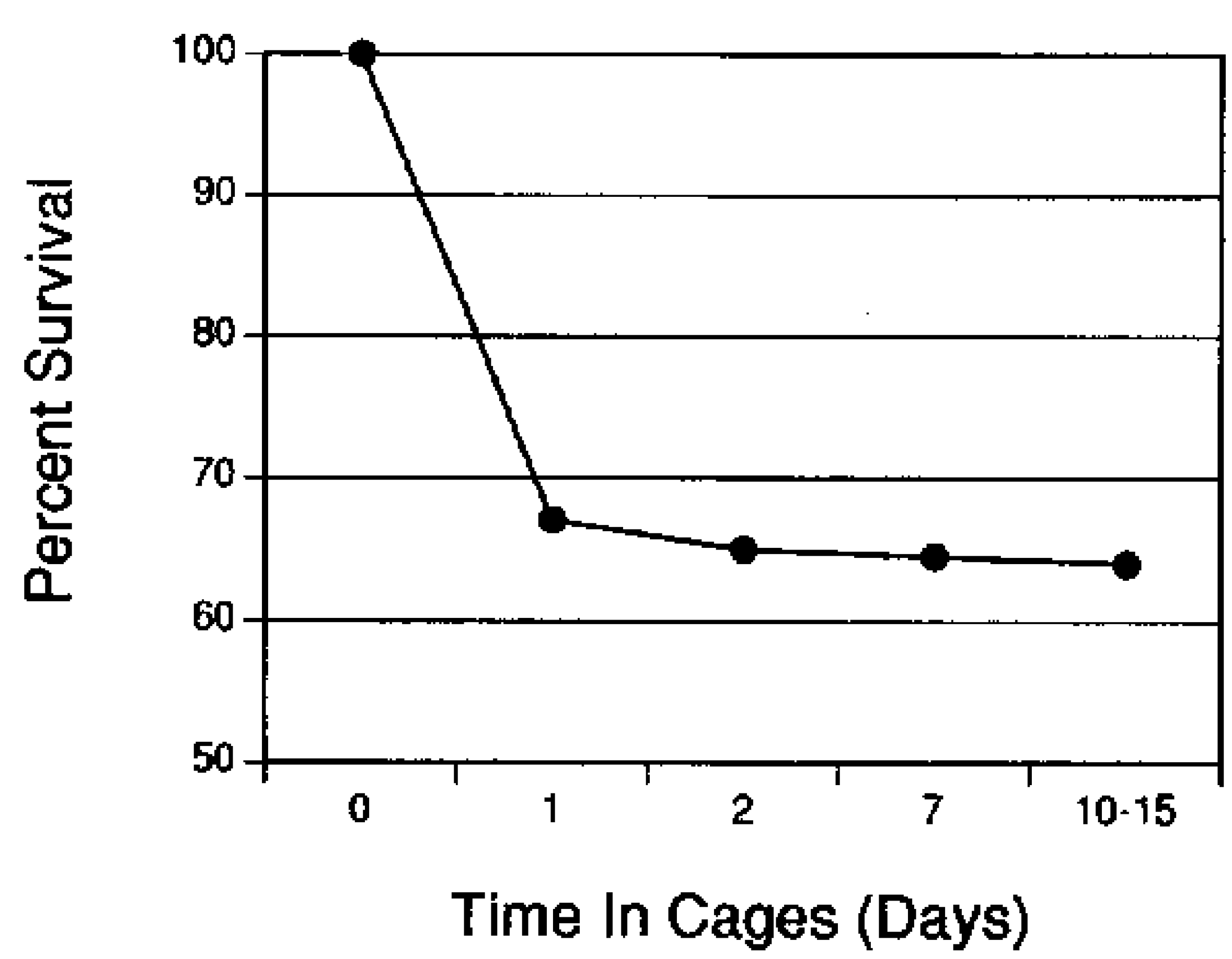

FIGURE 3.—Percentages of surviving red snapper by time after release in cages.

1% (2 of 149), 56% (18 of 32), and 56% (47 of 84) of fish captured at 21–24 m, 27–30 m, and 37–40 m, respectively (data include fish caught by headboat patrons as well as those represented in Table 1).

Of 90 red snapper released in the presence of scuba divers, 32 live and 2 dead fish were observed underwater. Limited visibility prevented divers from monitoring fish during their entire descent. Even though predators (i.e., sharks) were in the area, as evidenced by landings aboard the headboats, divers did not observe predation.

Discussion

Rapid retrieval of fish from depth may increase mortality due to hyperbaric trauma (Gotshall 1964; Collins, in press; Harper et al., in press). Commercial snapper boats have large-diameter reels powered by hand, electricity, or hydraulics, and these reels can retrieve fish much faster than the battery-powered, small-diameter sport reels we used in our cage study. In turn, our reels recovered fish more rapidly than the manual reels commonly used by recreational anglers and may have induced a somewhat higher mortality than recreational gear might cause.

Deployment of fish in cages introduced certain artifacts into the study of fish survival. Cages eliminated predation as a source of mortality. Several fish with everted gas bladders might have died floating at the surface had they not been forcibly returned to depth in cages. For these reasons, survival rates obtained from cage studies should be taken as an upper limit for survival of released red snapper. Similarly, comparisons between cage and surface release studies should be interpreted with care due to the effects of forced submergence and possible variations in retrieval speed on survival.

Internal trauma may not always be visible during external inspection of fish. Mortality of healthy-looking fish was similar to that of fish displaying obvious signs of stress ($P = 0.65$). Several factors may have contributed to this finding. For example, some expanding gas bladders may have been vented by fish hooks during ascent and consequently may not have been detected on arrival at the surface. Red snapper may have suffered internal hyperbaric trauma that subsequently proved lethal but was not evident to an observer immediately after the fish surfaced.

Determining estimates of predation on red snapper released in open water is extremely difficult. Complicating factors include limited underwater visibility, which may affect a diver's observational abilities as well as those of predator and prey; bottom time and depth restrictions of divers; difficulty in monitoring long-term survival; variability in the number of predators present when fish are released; and potential effects of the presence of divers on the behavior of predators and released fish. Although we did not observe predation, the predation rate on released snapper is expected to be higher than that for snapper not previously captured (Gotshall 1964). Fish that successfully return to the sea bottom may perish within hours or days because of injuries sustained during capture and handling or because of an impaired ability to escape predators or capture prey. In our surface release study, two snapper apparently died underwater during descent. Some fish displayed no apparent fear of divers (one fish was even touched by a diver's hand). Such abnormal behavior for a species that generally keeps a safe distance from divers (our observations) is probably related to stress.

Venting of everted bladders had little effect on survival of caged red snapper captured at 50-m depths, although our sample size was small. Render and Wilson (in press) also reported that gas bladder deflation had no significant effect on survival of red snapper captured at 20-m depths. In preliminary work on vermilion snapper *Rhomboplites aurorubens*, Fable (1993) found survival rates of 79% for apparently normal fish and 60% for fish with vented, expanded, but not everted bladders.

Our results combined with those from other cage studies suggest an inverse relationship between survival and capture depth (Table 3). Render and Wilson (in press) found 80% (200 of 250) survival for red snapper captured at 20-m depths and released at the surface into a 9-m-deep cage. Parker (1985) observed 79% (11 of 14) survival of red snapper captured at 22-m depths in the Atlantic Ocean off Daytona, Florida, and 89% (39 of 44) survival of fish caught at 30-m depths in the Gulf of Mexico off the Texas coast. In summary, survival rates of 79–89% were found for fish captured at 20–30-m depths compared with 64% for fish captured at 50 m. Variables that may affect interpretation of these combined results include geographic area, capture technique, and handling procedures.

Data are also available for other reef species. Of 82 vermilion snapper captured at depths of 27–30 m, 67% survived in floating cages during a 15–29-d holding period (Fable 1993). Survival was 71% for red grouper *Epinephelus morio* captured

TABLE 3.—Summary of pertinent studies on survival of surface-released and caged reef fish (after Parker 1991[a]).

Species	N	% survival	Depth (m)	Reference
Cage studies				
Red snapper	282	80	20	Render and Wilson (in press)
Red snapper	14	79	22	Parker (1985)[a]
Red snapper	44	89	30	Parker (1985)[a]
Red snapper	55	64	50	This study
Vermilion snapper	82	67	27–30	Fable (1993)[a]
Surface release studies				
Red snapper	140	99	21–24	This study
Red snapper	30	100	30	Parker (1991)[a]
Red snapper	31	90	27–30	This study
Red snapper	61	56	37–40	This study
Red grouper	23	65	44	Wilson[b]
Mixed	161	90	21	Collins (in press)
Mixed	248	89	36	Collins (in press)
Mixed	197	75	46–54	Collins (in press)
Mixed	109	84	46	Collins (in press)
Mixed	202	80	46	Collins (in press)

[a] Given in the appendix.
[b] Personal communication in Parker (1991).

at 44 m on rod and reel and released at the surface off the west coast of Florida (R. Wilson, University of South Florida, personal communication in Parker 1991). In a series of surface release studies involving a variety of reef species, survival was 90% at 21-m capture depths, 89% at 36 m, and 75% at 46–54 m (Collins, in press). In tag-and-release studies, fish first captured in shallower depths were recaptured in higher numbers, indicating higher survival relative to fish first caught at greater depths (Schirripa et al. 1993). This result is consistent with an inverse relationship between survival and capture depth. Survival was 78.5% for 1,884 fish (representing 79 species) captured in wire fish traps at depths of 31–82 m and released at the surface (Harper et al., in press).

The Gulf of Mexico Fishery Management Council's Reef Fish Fishery Management Plan established a goal of 20% spawning stock biomass per recruit, to be attained by the year 2000 (Muller 1990). Current red snapper bag limits can only be successful if survival of released fish is high. Existing data do not indicate high survival of fish caught from deep water. Recent yield-per-recruit and population dynamics estimates require accurate survival estimates for released red snapper (Waters and Huntsman 1986; Muller 1990). Incorporation of these values in the models will lower overall estimates of recruitment, spawning potential ratio, and yield per recruit.

Accurate estimates of survival for released fish are critical to developing successful management strategies. These estimates must account for depth of capture, mortality of floating fish unable to return to depth, mortality associated with capture and handling, delayed mortality (several days or weeks after release), predation, and perhaps season. Additional studies employing standard capture and handling techniques should increase the accuracy and repeatability of survival estimates. These studies should also address questions relating to the value of venting expanded gas bladders and to optimal field techniques for venting.

Acknowledgments

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Appendix: Unpublished References

Numerous unpublished references are of great importance for an understanding of previous studies on red snapper survival. Those referenced in this paper are given here as a separate listing.

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